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The National Aero-Space Plane Program

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Abstract

NASP--the National Aero-Space Plane--represents a vision--not just of an airplane flying at speeds of Mach 25---not just of a craft which can routinely go from earth to space and back--not just of great technological breakthroughs--but of America at its best, at its boldest, at its most creative. NASP is more than a program, more than the synergism of technologies, more than a capability that may change the way we move through the world and the aerospace around it. NASP is the focus for a transformation to what is possible.

NASP can be described in a number of ways: technological, programmatic, utilitarian, and philosophical. In each case, NASP represents a departure from the evolutionary approach and leads to a potential change in our thinking about what is possible. Let's review each aspect of the NASP program.

- The National Aero-Space Plane requires the synergism of several major technology breakthroughs.
- The National Aero-Space Plane requires a fundamental shift in our thinking concerning the management and implementation of high-technology programs.
- The National Aero-Space Plane opens up new possibilities in aeronautical and aerospace transportation that go beyond our traditional approaches in this area.
- The National Aero-Space Plane is the foundation upon which national cooperation, collaboration, and development can be built.

The Technological Challenge

The goal of the NASP program is to develop and demonstrate the feasibility of horizontal take-off and landing aircraft that utilize conventional airfields, accelerate to hypersonic speeds, achieve orbit in a single stage, deliver useful payloads to space, return to Earth with propulsive capability, and have the operability, flexibility, supportability, and economic potential of airplanes. In order to achieve this goal, technology must be developed and demonstrated which is clearly a quantum leap from the current approaches being utilized in today's aircraft and spacecraft. The NASP demonstration aircraft, the X-30, Fig 1, will achieve speeds of Mach 25, eight times faster than has ever been achieved with air-breathing aircraft. As it flies through the atmosphere from subsonic speeds to orbital velocities (Mach 25), its structure will be subjected to average temperatures well beyond that value. While rocket powered space vehicles minimize their trajectory through the atmosphere, the X-30 lingers in the atmosphere in order to use the air as the oxidizer for its ramjet and scramjet engines. The NASP aircraft must use liquid or slush hydrogen as its fuel and this will present a new challenge in aircraft fueling, storage, and fuel management. In order to survive the thermal and aerodynamic environment, the X-30 will be fabricated from a combination of highly advanced materials: refractory composites, metal matrix composites, and extremely high temperature superalloys. Because no large-scale test facilities currently exist to experimentally validate aerodynamic and propulsion operation above Mach 8, the design and operability of NASP aircraft must be carried out in "numerical wind tunnels" which utilize supercomputer-aided, computational fluid dynamics. Propulsion systems based on subsonic and supersonic ramjet combustion will propel the NASP X-30, and although these types of engines have been investigated in laboratories on the ground, no significant flight testing of these concepts has occurred. In the areas of aerodynamic design, flight control, thermal management, cooling systems, man-machine interface, and many other subsystems, NASP requires a major increase in capability in order to achieve its objectives. The technical and system integration necessary to achieve single-stage-to-orbit aircraft operations will be much more difficult than any ever attempted and will require a fundamentally new approach to aircraft design. In essence, NASP depends not on a single advance in technology, but on the synergism of breakthroughs in a number of major technical areas associated with aerospace vehicles, Fig 2.

The Technological Response

The NASP program has been carefully orchestrated to achieve the technological advances and integration needed to attain the goals of the X-30. There are five key areas of technology that are the focus of the NASP development program: engines, materials, aerodynamics, airframe/propulsion integration, and subsystems. In each area, development activities are underway to achieve major advance in technology within the next two years. In several cases, the approaches were initiated at the start of the NASP program in 1986, while the work in materials and subsystems are new ventures. Propulsion system feasibility and operability is the key development required in the NASP program and is the activity which is receiving the greatest attention. The basic engine approach for the NASP is a combined ramjet/scramjet air-breathing propulsion system which will provide the required thrust for much of the region between take-off and orbit, Fig 3. Various low-speed systems and the use of rocket systems for orbital insertion are being investigated. Ramjet and scramjet engines have been tested in shock and wind tunnel experiments and their feasibility is no longer in question. Current work is progressing to determine the overall specific impulse and effective thrust to weight parameters of a number of propulsion configurations which employ the basic concept. The first two years of propulsion activity concentrated on the analysis and subscale testing of key components of

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potential engine configurations and the construction of long duration wind tunnel facilities capable of testing full scale modules to speeds of Mach 8. The remaining two years will be spent gathering empirical data on complete engine systems and full-scale modules in order to determine the final engine design of the NASP X-30 configuration. During the first half of the current NASP development phase, a number of key material systems were identified as being critical to the feasibility of an air-breathing, single-stage-to-orbit aerospace vehicle. Because of the high temperature, high strength requirements of the NASP airframe and engine systems, most of the interesting configurations employed combinations of high temperature titanium aluminum alloys, carbon-carbon or ceramic composites, metal matrix composites, high creep strength materials, and high conductivity composites. Although the development of these materials has been underway for several decades, it was determined that the progress being made was insufficient to meet the requirements of the NASP program. Development of all five material systems was accelerated through the formation of a national materials consortium, focused on the five material types, with a greatly enhanced resource commitment, Fig 4. The consortium will fabricate, characterize, test, and develop the materials, fabrication processes, and manufacturing technologies needed to meet the NASP timetable.

The aerodynamics of hypersonic aircraft and aerospace vehicles has been the subject of considerable government, university, and industry attention for the past thirty years. Much is known about this subject and the NASP program is taking advantage of the wealth of information available in this country. However, the aerodynamic requirements of NASP vehicles are extremely stressful and sensitive to small changes in vehicle configuration and performance. In addition, the specific flight regime of the X-30 has not been extensively examined either through analyses, ground experimentation, or flight testing. Since the X-30 itself will examine the aerodynamics of air-breathing aerospace vehicles, the current development program has focused its effort on developing detailed computational fluid dynamic (CFD) models, Fig 5, and verifying these models using a large number of experimental tests. A massive CFD effort, utilizing a significant fraction of the total U.S. supercomputer capability, is underway to develop experimentally valid models to predict the inlet, combustion, and nozzle operation of the NASP. Three-dimensional, full Navier-Stokes codes which account for real-gas effects, chemical kinetics, and turbulent flow are being refined using shock tunnel, wind tunnel, and archival flight data in order to predict the critical NASP aerodynamic parameters to well within one percent of the desired values. Because the development of airframe and engine systems for the NASP is being pursued by separate organizations, the level of airframe-engine integration required of hypersonic aircraft has necessitated a major emphasis in this area, Fig 6. From the initiation of the program, this integration has commanded great attention and has received an enormous amount of government and contractor resources. Unfortunately, the constant evolution and changes involved in the challenging engine development has made the integration particularly difficult and, in some cases, of fleeting value. Nevertheless, the discipline and processes developed to insure airframe engine integration have laid a solid basis for the remainder of the program, where the integration activity will be further intensified between airframe and engine contractor teams. Although the previous four areas have demanded most of the resources of the NASP program, every subsystem of a hypersonic aircraft must be developed to the point where it will support the testing of an experimental vehicle. Major efforts are now underway to develop slush and liquid hydrogen systems, cryogenic tankage, fuel delivery systems, heat exchangers and turbopumps, avionics and cockpit systems, flight controls, and the instrumentation required to conduct the X-30 program. Specific efforts in each of these areas have been initiated and will be intensified as the experimental phase of the program is approached.

The Programmatic Challenge

It has been over eighty years since man first flew and over forty years since aircraft flew supersonically. For the past forty years, airplane speeds have advanced from Mach 1 to Mach 2, with only a few notable exceptions (the SR-71 is capable of Mach 3 flight and the rocket-powered X-15 achieved speeds around Mach 6). In general, however, it has taken us eighty years to go from Mach 0 to Mach 2. By contrast, NASP is attempting to increase the speed range of air-breathing airplanes to Mach 25 through a development and demonstration program of approximately ten years duration. During the 1950's and 1960's there was a great deal of activity which was aimed at the exploration of hypersonic vehicles and their possible configurations. Wind tunnels, shock tunnels, and experimental aircraft were fabricated and used to examine the key parameters of hypersonic flights. Unfortunately, that activity ceased early in the 1960's and the development of hypersonic aircraft has been in hiatus from that time until the initiation of the NASP program. A few government researchers and even fewer university and industry scientists kept the flame alive during those years, but the progress in hypersonics has been extremely slow. Although research in the critical areas of materials, CFD, and combustion has progressed because of other demands, the national capability at the beginning of the NASP program was extremely limited, dispersed, and unorganized. In order to conduct a challenging program like NASP, an extensive, competent, well-integrated and focused national team from industry, government, and academia must be developed. A key task of the development phase of the NASP program is not only to bring the key technologies to a state which will allow an X-30 airplane, but to form the team required to do the job. At the present time, there are over 5000 professionals working on the NASP program, as contrasted to 250 in 1985, Fig 7. While the principal goal of the NASP program is to demonstrate an aerospace vehicle capable of aircraft-like operations while achieving single-stage-to-orbit, the program has also become the basis for all hypersonic technology in the nation. Although the program must be focused towards the goals of the NASP X-30 demonstrator, it must also generate the technology which will allow a broad basis for future hypersonic vehicles and derivatives of the NASP demonstrator. Because of this, a key aspect of the program has been the continuation of a technology maturation effort of

$50-70 million/year to assure the availability of the base technology for future aerospace and hypersonic vehicles to all organizations involved in the NASP program. The management of the NASP program has emphasized collaborative, participative approaches since the goal of the program has been to develop a national team capable of leading us into the aerospace era of the 21st century. Government-industry decision making, consortia formation, and very strong associate contractor agreements with all parties have been featured throughout the program, Fig 8. At the Phase 3 decision point, the five key contractors in the program will be formed into a national team for the conduct of the Phase 3 experimental vehicle demonstration program. This will assure the best resources to carry out Phase 3 and will give the country a broad base of capability for the development and production of future aerospace vehicles.

The management of government resources has also taken on a national flavor. The program is a jointly managed effort involving five government agencies and most of the key national Research and Development Centers in the country, Fig 9. Government technical data is shared with all contractors in a timely fashion through elaborate technology transfer mechanisms and the development conducted by the government centers and laboratories is well-focused on the NASP challenge. This has resulted in extremely rapid technical progress and a minimum time to transition the technology to industry.

Through innovative management and organizational approaches, the NASP program is meeting its goal of developing breakthrough technology utilizing a broad, focused base of national resources in record time.

The Utility Challenge

Whenever a capability becomes available which fundamentally changes the way we look at our world, it is generally met with confusion and even resistance. The NASP program will result in technology which will allow the development of aircraft and aerospace systems which can fly at any speed, for any distance, from almost any area to any area, in and out of the atmosphere, on-demand, with flexible, economical operability, see Fig 10. In the traditional sense, this should provide us with enhanced commercial, civil, and military systems to perform the missions that airplanes and space launch systems currently satisfy. The viability and economic advantage of hypersonic commercial aircraft is still under study here in the U.S., but early results indicate that the advanced technology and potential systems resulting from NASP should open up new possibilities in this area. Civil and military space transportation using a single-stage-to-orbit, flexible, fast turnaround, and on-demand aerospace plane should be attractive for a significant fraction of the anticipated space traffic mission model. If we extrapolate what might be possible for space activities using an aerospace plane, the attractiveness of this kind of system should be even greater. There are literally dozens of current military missions which might make use of hypersonic or aerospace planes to enhance their effectiveness and detailed application studies are underway, particularly in the space delivery reconnaissance and force projection areas. But the greatest utility of the NASP program is undoubtedly in the application of both the technology and the systems to new areas of transportation, delivery, accessibility, and development which today do not exist. The discovery of the airplane was met with great skepticism by both the civilian and military community in the early 1900's. Yet, it is probably the single greatest discovery of the 20th century and has fundamentally changed our world. The aerospace plane may allow us to open up what lies above our world in a similar fashion.

The Philosophical Challenge

The NASP program is an experiment which tests the ability of this nation to work together to achieve revolutionary technology development and effectively translate that technology into viable products. Because it is succeeding in meeting that goal, it has become an example of government/industry collaboration, effective technology utilization, long-range visioning, and focused national commitment, see Fig 11. These are the very principles which were at the core of the outstanding progress that we as a nation achieved earlier in this century. They are the same principles which have been so successfully utilized by our economic competitors during the latter part of this century to capture a significant share of the markets and capabilities which once were exclusively ours. These are the principles for our nation's growth in the future as NASP is the foundation for our aerospace leadership in the 21st century.

Fig 1

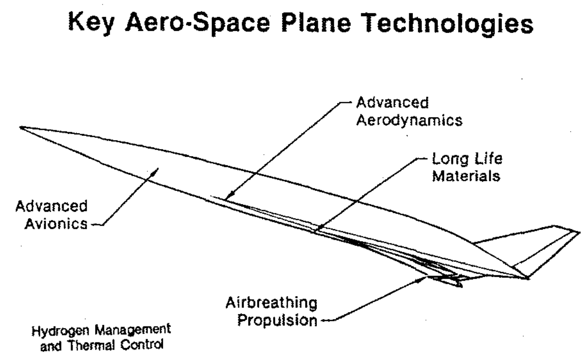


FIG 2

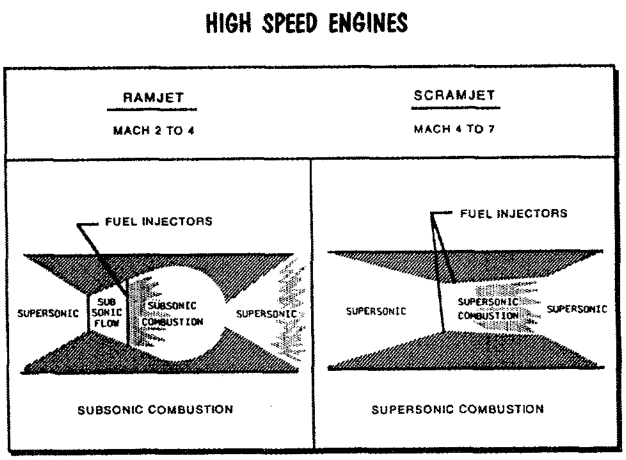


FIG 3

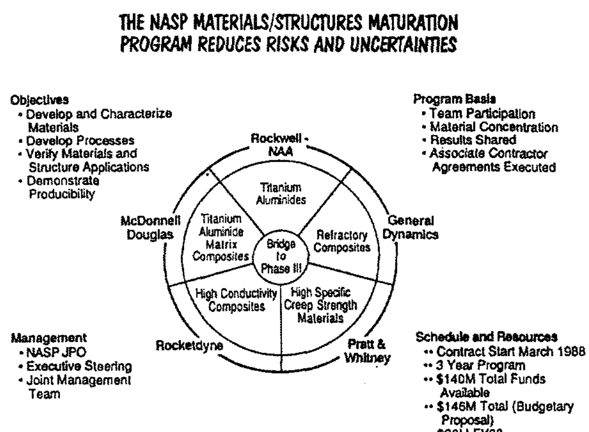


FIG 4

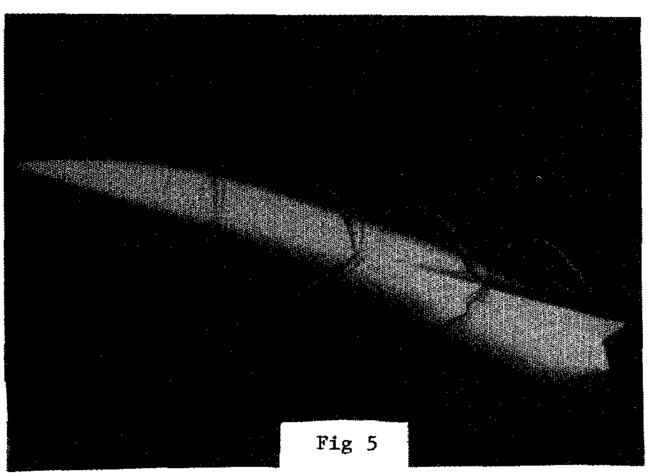


Fig 5

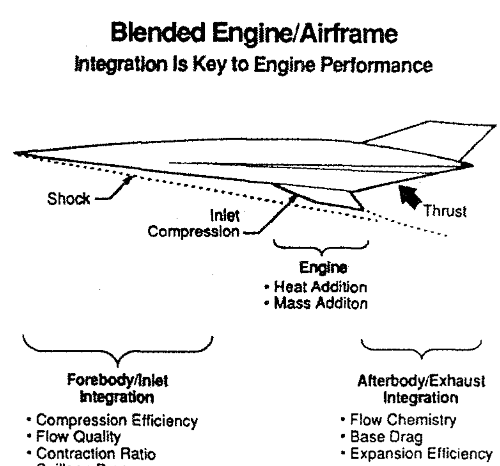
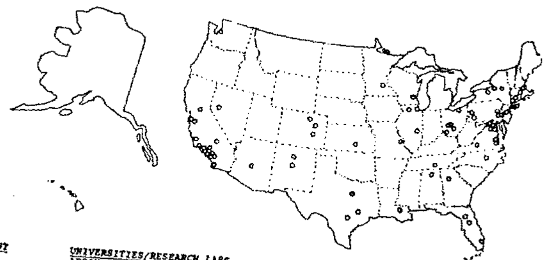


FIG 6



GOVERNMENT
DARPA
NASA - LANGLEY
- LEWIS
- AMES
- DRYDEN
AIR FORCE - AFSC
NAVY - NAVAIR
- ONR
- SPAWAR
SDIO
NATL BUR OF STDS

UNIVERSITIES/RESEARCH LABS
ARGONNE NATIONAL LAB
LOS ALAMOS NAT'L LAB
U. OF CALIFORNIA/SB
CARNEGIE-MELLON U.
HARVARD U.
U. OF ILLINOIS
JOHNS HOPKINS U./APL
U. OF NEW MEXICO
STATE UNIV. OF N. Y.
NORTH CAROLINA STATE U.
U. OF PITTSBURG
STANFORD U.
U. OF TEXAS
VIRGINIA POLYTECHNIC INST.
U. OF WISCONSON

INDUSTRY
AEROJET TECHSYSTEMS
AIR PRODUCTS
ALCOA
AMERICAN CYANAMID
ASTECH INC.
ASTRONAUTICS INC.
AVCO
BOEING
CALSPAN
CVI
DIRECTED TECHNOLOGIES
DUPONT AEROSPACE
DUPONT CHEMICAL
ENGLEHARD CHEM.
GARRETT AIRESEARCH
GENERAL APPLIED SCIENCE
GENERAL DYNAMICS
GENERAL ELECTRIC
GOULD
KENTRON
LOCKHEED
MARTIN-MARIETTA
MARQUARDT
MCDONNELL-DOUGLAS
MINNEAPOLIS HONEYWELL
PRATT & WHITNEY
ROCKWELL INTERNATIONAL
SAIC
SIKORSKY
SUNDSTRAND
UNION CARBIDE/LINDE
UTC ENERGY SYSTEMS
UTC RESEARCH CTR.
VIRGINIA RESEARCH INC.

FIG 7

NASP STRATEGY
MEETS THE CHALLENGE

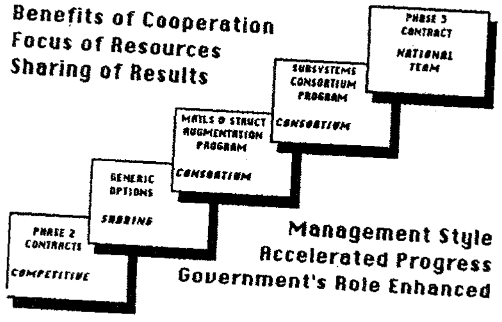


FIG 8

NASP MANAGEMENT STRUCTURE

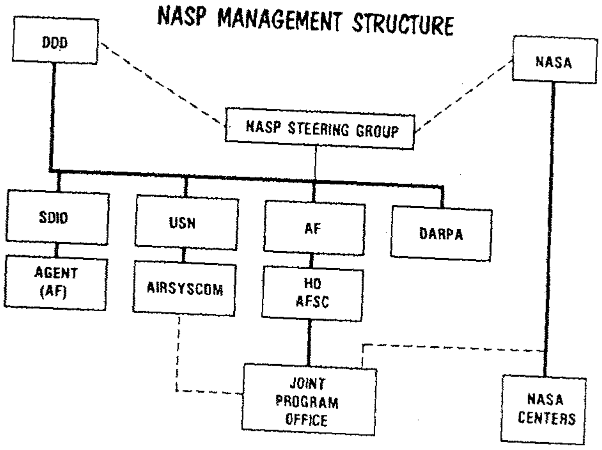


FIG 9

NASP - ENABLING SYSTEM FOR EVOLVING CIVIL/COMMERCIAL/MILITARY SPACE ARCHITECTURE

- ASSURED ACCESS TO SPACE
- LOW COST
- ON-DEMAND
- MULTI-FUNCTIONAL
  - SPACE TRANSPORT
  - RECONNAISSANCE
  - SPACE CONTROL

FIG 10

THE FUTURE

- GOVERNMENT/INDUSTRY COLLABORATION
- LONG RANGE PERSPECTIVE
- EFFECTIVE TECHNOLOGY UTILIZATION
- FOCUSED NATIONAL RESOURCES

FIG 11

NOTES